COASTAL WETLAND MONITORING USING OPTICAL AND SAR TIME SERIES

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There has been a growing use of remote sensing data to map and monitor wetlands due to their importance and the deterioration and area loss rate. Although coastal wetlands comprise less than 5% of the world´s terrestrial land mass the combination of high secondary productivity and accessibility to humans via land and water has made coastal wetlands attractive sites for human settlement for millenia. Particularly deltas rank among the most productive and dynamic systems on Earth, but are also the most densely populated regions, modified and vulnerable to natural processes and human activities.

The Lower Delta of the Paraná River is a major tidal freshwater wetland system, covering 2,700 km2. This delta is placed at the end of one of the largest Basin of South America, and at the mouth of the De la Plata Estuary. This delta is also next to important capital cities such as Montevideo (Uruguay) and Buenos Aires (Argentina). This region is the result of a dynamic synergism between fluvial inflow (from the Paraná and Uruguay rivers) and estuaric influence (De la Plata Estuary) (Kandus *et al.*, 1999). In fact, plant communities are nowadays affected by the El Niño events through the extensive flows of the Paraná River, and the persistence of these communities would be also restricted by any change in see level rise.

The hydrological regime is one of the most important factors that determine delta wetland species composition, nutrient cycles and fluxes, and productivity. Paraná River floods mainly affect the upstream portion of the delta, while the De la Plata River strongly influences the downstream portion of this region. Moon tides have a normal range of 1 m twice a day, but south-southeast winds can raise the water level up to 2.5 m over the average although floods last not more than several hours or a couple of days.

From the total area of the delta 56% is occupied by marshes, 33% of which are dominated by *Scirpus giganteus* (cortadera), and 22.5% by *Schoenoplectus californicus* (junco). The first community is characterized by heights of the order of 1.5m with a total above ground biomass of about 2656 g/m^2. The second one has a height of 2.5m, and a total biomass ranging from 650 to 1722 g/m^2 depending on its location on the delta and the degree of alteration.

In this way, due to the strategic location of this delta, it is of particular interest to develop wetland monitoring activities. Natural events and man actions taking place upstream the delta or in situ, while not always altering its areal extent, may modify its functional health because of a gradual degradation of the ecosystems present.

Phenological metrics such as vegetation indices derived from satellite and/or from hand-hold spectrometers have been associated with morphological or physiological stages at a point in time of plant growth, such as biomass, leaf area index and intercepted photosynthetic active radiation. Information derived from these metrics can be related to long term meteorological events, plant species distribution or human induced changes in terrestrial vegetation. Although NOAA AVHRR derived metrics have been extensively used, due to this system low spatial resolution, they are unable to capture landscape heterogeneity at wetland scales. The inherent heterogeneity of wetlands and the difficulty for direct access support the need for fine scale remote sensing systems for monitoring marsh health.

Thus, much effort has been made toward using simple vegetation indices like NDVI derived from high and mid resolution optical systems to estimate coastal marsh biomass and biomass production, differentiate wetland species and map species distributions (i.e. Gross et al., 1990, Zhang et al., 1993).

Imaging radars have distinct characteristics that make them of significant value for monitoring and mapping wetlands. Depending on frequency, polarization and ecosystems characteristics (herbaceous/woody vegetation), the microwave transmitted energy may penetrate the vegetation canopy, and the backscattered energy is also a result of electromagnetic interactions at the ground layer. The presence or absence of water in wetlands (which has a much higher dielectric constant than dry or wet soil) significantly alters the radar signature detected from these areas. Another important characteristic of imaging radars is their ability to operate independent of cloud cover and solar illumination, and therefore can monitor wetlands throughout periods where significant levels of precipitation are affecting water levels and vegetation growth patterns. These are capabilities not always available with visible and near-infrared spectrum sensors.

This paper addresses two issues: a) how coastal tidal freshwater marsh health and primary production are likely to be monitored using optical and SAR time series, and b) to test the interchangeability and /or complementary of optical and SAR data for monitoring vegetation growth and surface conditions.

15 LANDSAT 7 +ETM and 14 ERS-2 SAR images were acquired during the 1999-2001 period. Images were registered and rectified to UTM coordinate system. Digital counts in LANDSAT images were transformed to reflectance and atmospheric factors affecting path radiance were removed. NDVI, infrared indexes were calculated. SAR data were calibrated, co-registered, and temporally filtered to reduce the radiometric uncertainty due to speckle. Ancillary data include water level at Buenos Aires and Baradero ports for image acquisition times, and daily temperatures and precipitation for 1999 to 2001. During fieldwork plant community composition, stand density and plant biomass data were recorded (Figure 1) (www. USGS.... , Martinez et al., 2001). The Normalized Vegetation Index (NDVI) and coefficient of backscattering (sigma0) were calculated. Training samples of about 5 pixels each from 10 different cortadera marsh sites and 20 junco marsh areas were extracted and analysed.

Vegetation growth is characterised by seasonal annual cycles, subjected to growth limiting factors like water availability, temperature and evapotranspiration, among others. Real annual growth cycle was compared to the one generated by a stable factor like day length, which is not subjected to interannual variability. Seasonal changes in day length were modelled trough a sine function. For cortadera marsh mean annual NDVI, and Sigma0 signal curves were obtained fitting the Julian day-ordered series to the sine function attained (Elvidge et al. 1998).

Results indicate that optical and SAR temporal patterns of junco communities are complex, and difficult to interpret. In the upstream portion of the delta, this is due to fire dynamics and, in the recently formed bars of the De la Plata River, because both optical and radar signals are mainly conditioned by the effect of tides, and the effect of winds in the radar response. On the other hand, cortadera marshes results indicate that temporal trends in both, optical and radar signals show similar behavior reflecting green/death biomass temporal patterns, and having a stable performance in terms of optical and microwave response. Different areas, over a wide geographic range, have similar values of NDVI and Sigma0 for the same acquisition date, and no tidal influence. Interannual variability observed in both, optical and SAR time series, for cortadera marsh suggests a greening delay that is related to differences in both mean temperature and rain patterns.

This work shows that optical and radar data could become useful tools for wetland health monitoring and for determining the influence of environmental factors in wetland vegetation growth patterns. Furthermore, once the normal pattern has been modelled, deviations from normal could be determined, and explained. Also, it was possible to test the sensitivity of NDVI and sigma0 for these tasks.

One subject to emphasize is the importance of an adequate treatment of the time series for monitoring and comparability purposes. A significant outcome of this work is the development of an operative routine for pre-processing optical and SAR data. In addition this work constitutes a clear example of how NDVI and sigma0 may become valuable and comparable metrics for temporal analysis in wetlands.

Among the limitations of this work, we can mention the absence of optical data during winter (due to cloud cover), the incomplete SAR series and the lack of simultaneity between satellite data and fieldwork. To further understand the temporal behaviour and explain the observed variations, 2001/2002 image comparison is in progress, as well as field campaigns. Nevertheless, in spite of the limitations mentioned, the results are encouraging.
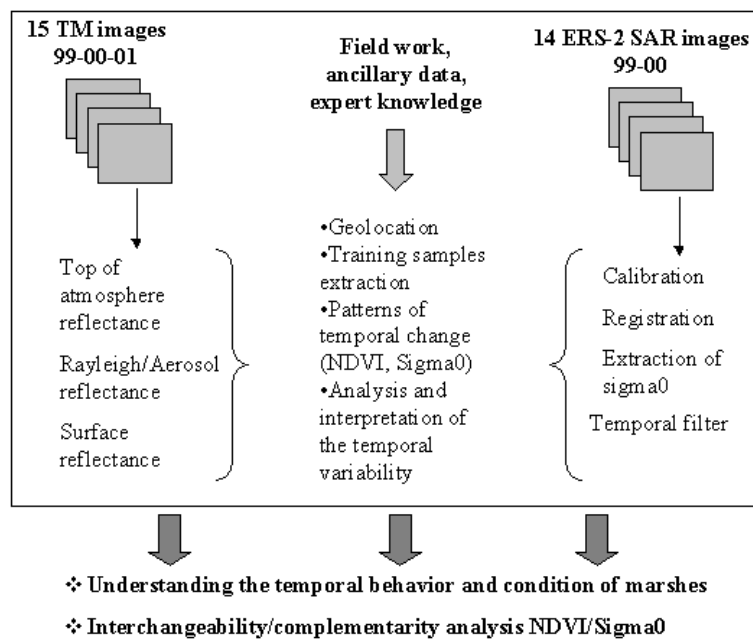
Figure 1. Data and methodology

References

Zhang, M., L. Ustin, E. Rejmankova, and E. W. Sanderson, 1993. Monitoring Pacific Coast Salt Marshes using Remote Sensing. *Ecological applications* 7(3): 1039-1053.

Gross, M. F., M. A. Hardisky and V. Klemas, 1990. Inter-Annual Spatial Variability in the Response of Spartina Alterniflora Biomass to Amount of Precipitation. *Journal of Coastal Research* 6(4): 949-960.

Kandus, P. H. Karszenbaum and L. Frulla, 1999. Land cover classification system for the Lower Delta of the Paraná River (Argentina): Its relationship with LANDSAT Thematic Mapper classes. *Journal of Coastal Research*, 15 (4): 909-926.

Martinez , J.M., H. Karszenbaum, T. Le Toan, P. Kandus, J. Tiffenberg, P. Pratolongo, and G. Parmuchi, 2001. Detecting Anthropogenic and Natural disturbances in Wetland Ecosystems with Multitemporal ERS 2 Data. *Retrieval of Bio-and Geophisycal Parameters from SAR data for Land Application. ESA publication SP-475*, pp. 111-115.

Elvidge, C. D., T. Miura, W. T. Jansen, D. P. Groeneveld and J. Ray; 1998. Monitoring Trends in wetland Vegetation Using a Landsat MSS Time Series. In *Remote Sensing Change Detection. Environmental monitoring Methods and Applications*. R.S.Lunetta and C.D. Elvidge Eds. Ann Arbor Press, Cap. 12 pp. 191-210.